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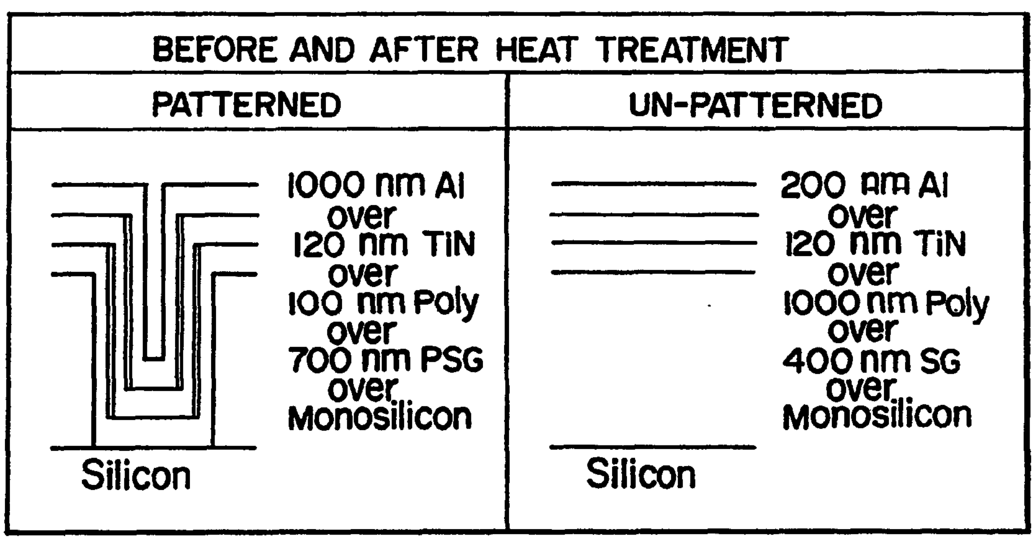
(54) Title: STABILIZATION OF THE INTERFACE BETWEEN ALUMINUM AND TITANIUM NITRIDE



(57) Abstract

A semiconductor device comprises at least one metal interconnect layer, a titanium-based barrier layer in contact with the metal interconnect layer. The metal interconnect layer contains titanium in an amount up to the limit of solid solubility at the peritectic temperature. The arrangement is effective to reduce hillock, spike, and notch formation in the semiconductor device.

INTERNATIONAL SEARCH REPORT

International Application No PCT/CA 92/00185

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 H01L23/485

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl. 5	H01L

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category°	Citation of Document,[11] with indication, where appropriate, of the relevant passages[12]	Relevant to Claim No.[13]
X	PATENT ABSTRACTS OF JAPAN vol. 12, no. 385 (E-668)14 October 1988 & JP,A,63 129 662 (FUJITSU LTD) 2 June 1988 see abstract	1,14
A	PATENT ABSTRACTS OF JAPAN vol. 10, no. 150 (E-408)31 May 1986 & JP,A,61 008 971 (NIPPON GAKKI SEIKO KK) 16 January 1986 see abstract	1,8,14
A	EP,A,0 304 728 (SIEMENS AG) 1 March 1989 see column 1, line 37 - line 48; claim 1	1,8,14
P,A	EP,A,0 430 403 (SGS-THOMSON MICROELECTRONICS,INC) 5 June 1991 see column 3, line 45 - column 4, line 32	1,14

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° Special categories of cited documents :[10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
20 JULY 1992	29. 07. 92
International Searching Authority	**Signature of Authorized Officer**
EUR PEAN PATENT OFFICE	GREENE S.K. SK Greene

1

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category °	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	US,A,4 999 160 (LOWREY ET AL) 12 March 1991 see column 3, line 11 - line 36 ---	1,14
A	US,A,4 107 726 (SCHILLING) 15 August 1978 see column 1, line 31 - line 62; figure 1D ---	8

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. CA 9200185 SA 58781

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A-0304728	01-03-89	JP-A- 1072542	17-03-89
		US-A- 4910580	20-03-90
EP-A-0430403	05-06-91	JP-A- 3220751	27-09-91
		US-A- 5070391	03-12-91
US-A-4999160	12-03-91	None	
US-A-4107726	15-08-78	US-A- 4164461	14-08-79

For more details about this annex : see fficial Journal of the European Patent ffice, No. 12/82

This limit of solid solubility can be estimated by looking at various aluminum-titanium phase diagrams shown in figures 14a to 14g.

Table 4 summarizes published wt % Ti solubility limits at the eutectic temperature of 665.1°C, at the peritectic temperature of 660.4°C, at the TiN barrier limit temperature of 550°C, which is the highest temperature that TiN can see before aluminum penetration and attack, and at the metallization limit temperature of 500°C which is the highest temperature that the semiconductor device will see during and/or after aluminum metallization.

TABLE 4

Sample No.	665.1°C	660.4°C	550°C	500°C
1	0.15	>1.00	?	?
2	0.19	0.28	<0.20	<0.20
3	0.05	0.29	0.16	0.14
4	0.15	1.20	?	?
5	0.15	1.18	0.37	0.20
6	0.15	0.32	?	?
7	0.15	1.08	0.40	0.22
8	0.15	1.08	0.40	0.22
9	0.16	?	?	?
10	0.15	1.00	?	?
11	?	1.25	?	?

This table shows that up to 0.19 wt % Ti can enter in solution in the aluminum alloy melt at the eutectic temperature of 665.1°C; that titanium supersaturated aluminum alloy solid solution containing up to about 1.25 wt % Ti can be obtained at the peritectic temperature of 660.4°C; and that up to about 0.40 wt % Ti can dissolve at 550°C and that up to about 0.22 wt % Ti can enter solid solution at 500°C.

The bulk resistivity of pure aluminum is 2.65 μΩ.cm at r om temperature. Th bulk resistivity of aluminum-titanium alloys increases at a rate of 2.88

μΩ.cm per wt % Ti in solid solution and at a rate of 0.12 μΩ.cm per wt % Ti out of solution. It is then necessary to keep the titanium content of the aluminum alloy at a minimum to ensure the lowest possible bulk resistivity.

The most common aluminum alloy that is used as interconnect material of devices without a barrier layer contains (98.5 wt % Al) - (1.00 wt % Si) - (0.50 wt % Cu) and has a theoretical bulk resistivity as high as 3.84 μΩ.cm when all the silicon and copper is dissolved in aluminum. This represents 1.24 times the bulk resistivity of pure aluminum.

The aluminum alloy containing about 0.40 wt % Ti, which is needed to stabilize the (poor quality TiN)/(aluminum alloy) interface to a temperature of up to 550°C, has a theoretical bulk resistivity that can be as high as 3.80 μΩ.cm when all the titanium is dissolved in aluminum. This represents 1.43 times the bulk resistivity of pure aluminum

In accordance with the invention, aluminum alloys used as the interconnect layer contain titanium in contact with TiN layers in devices exposed to temperatures lower than 550°C and preferably in the 450-500°C range. The titanium content may be as large as the limit of solid solubility at the peritectic temperature of 660.4°C, which is 1.25 wt %, but is preferably lower than 0.40 wt % and can be as small as 0.05 wt %.

The titanium containing aluminum alloy can be deposited as a sputtered film. It is also possible to deposit this alloy by co-evaporation of aluminum and titanium, by low pressure chemical vapour deposition, LPCVD, by metalorganic chemical vapour deposition,

Claims:

1. A semiconductor device characterized in that it comprises at least one metal interconnect layer, a metal compound based barrier layer in contact with said metal interconnect layer, and said metal interconnect layer containing said metal of said compound in an amount up to the limit of solid solubility at the peritectic temperature.

2. A semiconductor device as claimed in Claim 1, characterized in that said titanium-based barrier layer is titanium nitride.

3. A semiconductor device as claimed in Claim 1 or 2 characterized in that said metal interconnect layer is selected from the group consisting of: aluminum, gold, tungsten and copper.

4. A semiconductor device as claimed in Claim 2 or 3, characterized in that the titanium nitride in said barrier layer is a stoichiometric single-phase, face-centered δ-TiN.

5. A semiconductor device as claimed in Claim 2 or 3, characterized in that the titanium nitride in the barrier layer is non-stoichiometric single phase face-centred cubic δ-TiN.

6. A semiconductor device as claimed in Claim 2 or 3, characterized in that the titanium nitride in the spike suppression layer is tetragonal ϵ-Ti_2N.

7. A semiconductor device as claimed in Claim 2 or 3, characterized in that the titanium nitride in the barrier layer is a s lid solution of two or more of the compounds s l cted from the group consisting of:

stoichiometric single phas , face-centred cubic δ-TiN; non stoichiometric single phase face-centr d δ-TiN; and tetragonal ϵ-Ti_2N.

8. A multilayer semiconductor device characterized in that it comprises first and second aluminum alloy interconnect layers, a titanium nitride barrier layer over said first aluminum alloy interconnect layer, and a dielectric layer over said barrier layer, said first aluminum alloy interconnect layer containing titanium in an amount between 0.05 wt % and the limit of solid solubility at the peritectic temperature.

9. A multilayer semiconductor device as claimed in Claim 8, characterized in that the amount of titanium on the first interconnect layer is less than 0.4 wt %.

10. A multilayer semiconductor device as claimed in Claim 8 or 9, characterized in that titanium nitride in the barrier layer is stoichiometric single phase, face-centred cubic δ-TiN.

11. A multilayer semiconductor device as claimed in Claim 8, characterized in that the barrier layer is a non-stoichiometric single-phase, face-centred δ-TiN.

12. A multilayer semiconductor device as claimed in Claim 8, characterized in that the titanium nitride in the barrier layer is tetragonal ϵ-Ti_2N.

13. A multilayer semiconductor device as claimed in claim 8, characterized in that the titanium nitride in the barrier layer is a solid solution of two or more compounds selected from the group consisting of: stoichiometric single phase, face-centred cubic δ-TiN,